(10.)

With the author's compliments

CONTRIBUTION TO THE MORBID ANATOMY AND PATHOGENESIS OF CHRONIC INTERNAL HYDROCEPHALUS.

By HAROLD J. STILES, M.B., F.R.C.S.Ed.

Reprinted from Volume Fourth of the Edinburgh Hospital Reports.
Edinburgh and London, Young J. Pentland, 1896

Contribution to the Morbid Anatomy and Pathogenesis of Chronic Internal Hydrocephalus.

By Harold J. Stiles, M.B., F.R.C.S.Ed.

In this paper I propose to describe the morbid anatomy of two typical cases of chronic internal hydrocephalus, and to make a few remarks upon the pathogenesis of the condition. It may be well, however, in the first instance, to state shortly the main clinical facts of each case.

Case 1.—T. R., æt. 5 months, was transferred to the surgical side of the out-patient department of the Royal Hospital for Sick Children by my colleague Dr. Cumming.

The infant presented all the clinical features of a well-marked case of chronic hydrocephalus. The cranium was subglobular, with a horizontal circumference of 19 in. The fontanelles and sutures were widely expanded, the superficial veins of the scalp were much dilated, the face small and pointed, the eyes were staring and somewhat divergent, with the sclerotics visible above the cornea, and the body was small and wasted. The mother stated that the child appeared to see and hear quite well, but she complained that he took frequent fits of crying, especially at night. His appetite was rather voracious.

History.—The infant appears to have been healthy at birth, and the labour was normal. The enlargement of the head was first noticed when the child was a fortnight old, and rapidly increased; the crying fits became more severe and frequent. There had been no convulsions, and there was no history of injury to the head.

The parents were living and healthy, but with an alcoholic tendency on the part of the father. Of the five other children, the third died of "croup," the fifth was premature,

and the remaining three are alive and well. Although no definite history of syphilis could be obtained, it was a little doubtful if such a taint could be altogether excluded.

Progress and Treatment. — The child was under treatment from the time it was 8 weeks old until its death at the age of 5 months.

The main facts in the progress of the case may be gathered from the following table :—

Date.	Circumference of head (in inches.)	From ear to ear over vertex (in inches).	Fluid removed (in ounces).
Sep. 27, . .	17¾	10½	
Oct. 7, . .	19	11½	1
,, 11, . .	19¼	11½	
,, 18, . .	19½	11½	2
,, 21, . .	19¾	11½	
,, 25, . .	20¼	11½	
,, 28, . .	20½	12¼	
Nov. 4, . .	21	12¼	2½
,, 11, . .	21½	13	
,, 18, . .	21½	13	
,, 25, . .	20½	12½	3
,, 29, . .	21½	13	
Dec. 5, . .	21¾	13¼	
,, 19, . .	22	13½	3
Jan. 2, . .	22½	14	4½
,, 19, . .	23	14½	5½
Feb. 4 (died), .	23½	15	7

Having regard to the fact that the child was an out-patient, and to the unsatisfactory results which have been obtained by continuous drainage, it was decided to try the effect of repeated tappings, care being taken to use every precaution to avoid the introduction of micro-organisms. After shaving and thoroughly purifying the skin, a small metal trocar and cannula (previously sterilised by boiling) was introduced into the ventricle through the large membranous area of the anterior fontanelle, about 1½ in. from the middle line, on the right and left sides alternately. After withdrawing the fluid, the puncture was securely closed by a large and thick collodion dressing, over which corrosive wool and a domette bandage was applied to keep up a certain amount of pressure. No anæsthetic was used.

It will be seen from the above figures that this treatment did not prevent the progressive enlargement of the head; nevertheless, the mother was quite satisfied that the child was always brighter and screamed less for a few days after tapping. If the necessary precautions be taken to avoid the introduction of micro-organisms into the cranial cavity, the little operation may be said to be devoid of danger, and is, I think, on the whole, the one to be recommended. It is true that such treatment only very exceptionally effects a cure, still, cases have from time to time been reported by John Hern ([14]) and others in which it has apparently done so, although it is difficult to say in what proportion of these cases the same result might have occurred without tapping. Every care should be taken to prevent leakage from the puncture. This is best done, firstly, by using a small cannula, and, secondly, by applying a large collodion dressing. In spite of these precautions, on one occasion (23rd November) leakage did occur,—as a result, the mother says, of a severe screaming fit when the child was being bathed. Clear cerebro-spinal fluid continued to drain away for five days, and then ceased spontaneously. The result of the leakage was to cause some falling in of the fontanelles, and a reduction of the circumference of the head by 1 in. Two days later, however, the head had regained its former size and tension. The fluid drawn off at the next tapping was quite clear and sterile, thus proving that sepsis had not resulted from the leakage.

In spite of the treatment, the child gradually became more and more emaciated and drowsy, and one morning the mother found him dead in bed. He never had any general convulsions, but during the last few weeks of his existence he had frequent twitchings, more especially of the lower extremities, and some nystagmus.

Case 2 was under the care of Dr. Carmichael in the Children's Hospital, and I am indebted to him for permission to make the following extract from the Hospital record of the case.

E. S., æt. 20 months; admitted 5th February 1892. Complaint: chronic hydrocephalus.

Family history.—Father died of Bright's disease; mother alive and healthy. Five other children, æt. 14, 10, 6, and 5 years respectively, and all healthy, with the exception of the eldest, who suffers from chorea. No mention of syphilis.

The patient was quite well until she was 3 months old, when she took eight fits in one day. The fits began with violent screaming, followed by irregular movements of the right arm and leg, and turning up of the eyeballs. She never had any more fits, but remained dull and unable to hold up her head.

On the child's admission to Hospital, her head was distinctly hydrocephalic, and there was a bed-sore over the right parietal bone the size of a shilling. The expression was vacant and staring, and the body somewhat emaciated. There was no paralysis of the extremities, but the hands were kept clenched and the legs rigidly extended. Some days after admission a second bed-sore formed over the opposite parietal bone. A few days before the child died, vomiting set in, and the temperature became elevated. Death took place on the thirtieth day after admission, and was preceded by a more or less continuous convulsive state which lasted for several hours.

Dr. Bruce, who made the post-mortem, gave a preliminary report of the brain, which, after carefully removing, he placed in Müller's fluid, in order to harden it prior to a subsequent more thorough investigation. On hearing that I was investigating the subject, he very kindly placed the specimen at my disposal.

Before describing it, I may here make the following extract from the post-mortem book: "Horizontal circumference of cranium, 20 in.; anterior fontanelle, 3 in. × 2½ in.; posterior fontanelle, closed. Skull cap less than 1 mm. thick. Dura mater, normal. Convolutions and sulci effaced, and brain converted into a cyst. Considerable increase of arachnoid fluid at the bases, and membranes here œdematous, otherwise normal. Lateral ventricles enormously dilated. A small cyst upon the upper aspect of each choroid plexus. A few fine granules here and there upon the ependyma."

Morbid Anatomy.

As there are few diseases the pathology of which is more obscure, I was anxious, in my own case, to make a thorough examination of the brain. Having obtained permission to do so, I had the head frozen entire, in order that the relation of the parts might be studied as nearly as possible as they existed during life; and to ensure its being frozen throughout, it was kept in the freezing mixture for four days. It was then sawn through into slabs in the vertical coronal plane. Tracings of the more important sections were made at once upon glass, transferred from this to tracing paper, and finally to the block upon which the water-colour drawings were made. The slabs were kept carefully frozen while the drawings were being executed, a little more detail being put into them after the parts had been allowed to thaw for some time, so as to admit of some of the structures being more thoroughly identified. The slabs were then put into spirit, and subsequently more completely dissected.

On account of the profound alterations which the brain had undergone as the result of the disease, considerable difficulty was at first experienced in identifying and obtaining an accurate description of some of the structures, more especially those about the base of the brain. The sectional method of investigation, while it possesses many advantages, has at the same time its disadvantages, one of them being the difficulty which arises in tracing the anatomical continuity of certain of the structures. With the help, however, of Dr. Bruce's specimen, which had been well hardened in Müller's fluid and carefully preserved, I have been able to clear up several points regarding which I was unable to satisfy myself merely from the examination of the frozen slabs.

The pathogenesis of the majority of the cases of chronic hydrocephalus is a subject concerning which there is great difference of opinion, and about which it must, I think, be confessed we know very little. Before we can hope to acquire further knowledge on this matter, we must, in the first place, make ourselves better acquainted with the morbid anatomy of the condition. As the descriptions of the morbid anatomy of

the brain in hydrocephalus are rather fragmentary, and upon many points contradictory, I shall describe the specimens with some anatomical detail. Sir George Humphry (15) has made the anatomy of hydrocephalic skulls the subject of a most instructive and interesting paper, to which I would refer the reader for a full account of the subject. There are several excellent specimens in the museum of the University and of the Royal College of Surgeons; and I am indebted also to my colleague, Dr. John Thomson, for kindly allowing me to make use of a beautifully prepared skull from a case which had been under his care. It would serve no useful purpose to refer individually to these various specimens; it will be enough to mention some of their more important features, and to endeavour to show how the morbid changes have been brought about.

In the frozen specimen, the greatest horizontal circumference measured 23½ in.; the coronal arc, from ear to ear, 15½ in.; from glabella to inion, 16 in. On account of the wide expansion of the upper part of the frontal suture, as well as of the whole of the sagittal suture, the anterior and posterior fontanelles were thrown into one, so that the vertex was almost entirely membranous. This membranous area measured 12½ in. antero-posteriorly by 9 in. transversely; at its narrowest part, between the parietals, it measured 4 in.

Trousseau has very aptly compared the separation of the bones of the vault to the falling back of the petals of an opening flower. We must remember, however, that the enlargement of the head is brought about also by a great increase in the size of the bones themselves, due, no doubt, to ossification occurring *pari passu* with the stretching. If the cranial box were everywhere equally expansile, the pressure exerted by the accumulating fluid within it, being equal in all directions, would result in a uniform enlargement without any change in form. Since, however, the skull, from its architecture, is not equally expansile in all its diameters, there is produced, along with the enlargement, a change in form which is more or less characteristic of the disease. On account of the much greater widening out of the sagittal as compared with the coronal and horizontal system of sutures,

the expansion of the cranium is much greater in the traverse than in the antero-posterior direction. The cephalic index (index of breadth) is about 90 as compared with that of an average skull, in which it is 76. The frontal suture is less extensively opened up, on account of the wedging in of the frontal bone at the base of the skull between the wings of the sphenoid, and in consequence also of its connections with the ethmoid and with the bones of the face. The transverse diameter in the parietal region is thus relatively much greater than that in the frontal region, so that when looked down upon the vertex has a more or less ovoid outline. The increase of the antero-posterior diameter is due mainly to the enlargement of the bones of the vault, more especially of the parietals, assisted by the thrusting forward of the frontals (whereby they come to overhang the face), and to the folding downwards, as it were, of the superior portion of the occipital bone towards the base of the skull, so that the posterior pole of the cranium comes to be formed by the posterior fontanelle. This straightening out of the occipital bone gives rise to the great elongation of the occipital region behind the neck, and no doubt increases the tendency of the head to fall back by throwing the centre of gravity behind its articulation with the spine. There is little or no opening up of the lower part of the coronal suture, which fact, combined with the great expansion of the sagittal suture, is the main factor in producing the pathological brachicephalic condition of the skull. The increase of the vertical diameter, and of the basi-bregmatic height, is due mainly to the enlargement of the parietals, and, to a less extent, to the opening up of the horizontal sutures between the parietals above and the temporals and occipitals below. On looking at the base of the skull, it will be seen to be very distinctly vaulted downwards, so that the foramen magnum and posterior fossa lie in a plane considerably below that of the hard palate. The average index of height in the hydrocephalic skulls to which I have had access is 80, as compared with 71, which is the average of that of a normal British skull. It is the great increase of the height and breadth indices which gives to the typical hydrocephalic cranium its more or less globular shape,

combined with some degree of squareness, due to localised bulging at the frontal and parietal eminences. The bones of the vault are 1 mm., or less, in thickness, and are, of course, devoid of diploe.

The enlargement of the bones is not confined to those which enter into the formation of the vault, for those at the base are also expanded. The expansion of the lesser wings of the sphenoid assist materially in enlarging the anterior fossa. The clinoid processes, the groove for the optic nerve, and the sella turcica, are all well marked. The basi-sphenoid and basi-occiput remain much about their normal size, as also do the petrous temporals, which appear, therefore, relatively to the other bones, to be unduly small. The grooves for the meningeal vessels are very poorly marked; those for the venous sinuses are shallow, but widened. The foramina of exit for the nerves are relatively very small.

The greater wings of the sphenoid and the squamous temporals, forming the middle fossa of the base, are bulged forwards and outwards, so as to almost obliterate the zygomatic and temporal fossæ. The zygomatic arch, in consequence of its connection with the temporal bone, instead of being horizontal, as it normally is, becomes directed obliquely backwards, downwards, and outwards.

Normally, the upper border of the external auditory meatus in the child is only slightly below the level of the infraorbital margin. In the advanced hydrocephalic skull, however, it is on a level with the alveolar border of the lower jaw, and the auricle is correspondingly thrust downwards, and overhung by the cranium. According to Symington ([19]), the membrana tympani is inclined at much the same angle in the child as in the adult, namely, at 45°; in hydrocephalus it may become quite horizontal.

The most striking feature about the facial portion of the skull is, of course, its diminutive size as compared with the cranium; the triangular and pointed appearance is due to the way in which it tapers from the expanded forehead to the chin. The remarkable changes produced upon the orbits are well known, and are largely responsible for the characteristic expression presented by the unfortunate sufferers. The

supra-orbital arch is dragged upwards to such an extent by the expansion and stretching of the frontal bone, that the vertical diameter of the orbital outlet, which in the child is normally less than the traverse, now comes to exceed it. The roof of the orbit—normally arched upwards and directed

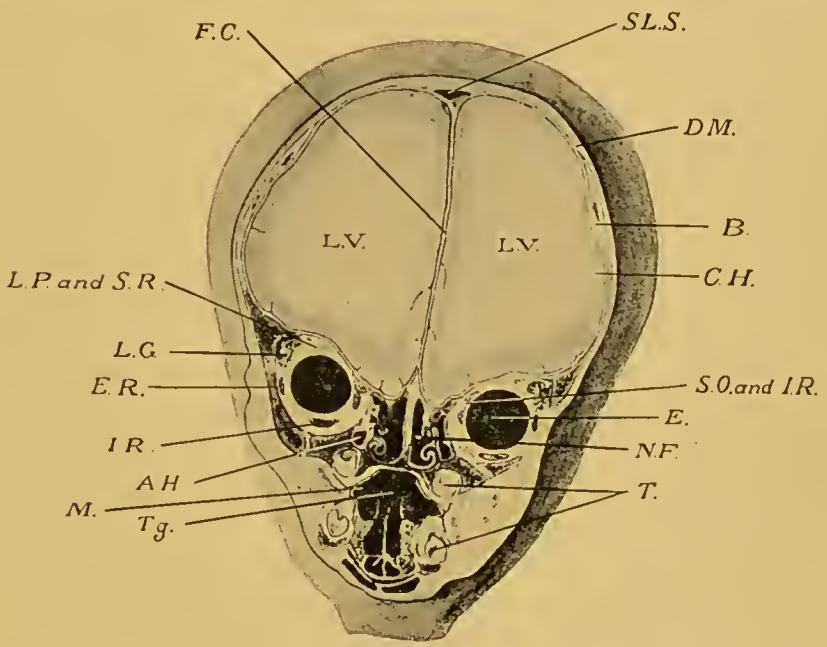


FIG. 1.—Coronal section, viewed from before, passing through frontal region, orbits, nasal cavities, and mouth.

L.V., lateral ventricles; *F.C.*, falx cerebri; *S.L.S.*, superior longitudinal sinus; *D.M.*, dura mater; *B.*, frontal bone; *C.H.*, cerebral hemisphere; *L.P.* and *S.R.*, levator palpebræ and superior rectus; *S.O.* and *I.R.*, superior oblique and inferior rectus; *E.R.*, external rectus; *I.R.*, inferior rectus; *E.*, eyeball; *L.G.*, lachrymal gland; *N.F.*, nasal fossa; *A.H.*, antrum of Highmore; *M.*, mouth; *T.*, teeth.

(Figs. 1 to 5 are from coronal sections of the frozen hydrocephalic head of Case 1.)

only slightly forwards—is pushed downwards and markedly forwards, especially its inner half, which, moreover, is usually more or less membranous. The inner half of the supra-orbital arch may become completely obliterated by the gradual merging of the frontal into the orbital surface of the bone. The peculiar staring expression of the hydrocephalic child, due to the exposure of the white sclerotic above the cornea,

is familiar to all, and is usually attributed simply to the pushing downwards of the eyeball beneath the lower eyelid; it is certainly dependent also upon the elevation of the supra-orbital arch, and to the stretching of the skin of the forehead to such an extent that the upper lid is no longer able to cover so much of the globe. In our own specimen, careful attention was directed to the ocular muscles and their nerves, in order to ascertain whether they had any share in the production of the altered position of the eyeballs. In the frozen slab, represented in Fig. 1, all the orbital muscles were well developed, with the exception of the levatores palpebræ superiores, and the superior recti, which on subsequent dissection were found to be atrophied. The ptosis, and the downward rotation of the eyeball, conditions almost invariably met with in the later stages of the disease, are thus accounted for. The divergence which generally co-exists is due to the greater displacement of the inner and thinner portion of the orbital roof, and possibly also to the comparative freedom from pressure enjoyed by the sixth nerve as compared with the third and fourth nerves.

Although the face looks so diminutive when contrasted with the cranium, it is in reality broader than normal. This is due not only to the expansion of the frontal bone, but also to the broadening of the ethmoid, which increases the distance between the eyeballs. The upper part of the face is farther broadened by the opening out of the angle of the malar bone, due to the bulging of the middle fossa of the skull. With the exception of an increase in the distance between its condyles, the lower jaw undergoes no change, so that the chin gives one the impression of being unduly narrow and pointed. The height of the nasal fossæ does not appear to undergo any alteration. In Fig. 1 the frontal lobes of the brain are seen to be dipping down between the orbits, but this, it will be remembered, is a perfectly normal condition, and does not appear to be exaggerated in our specimen; nor could it well be, on account of the buttresses formed by the septum and outer walls of the nasal fossæ.

As there are one or two points of more or less anatomical interest shown in Fig. 1, I may incidentally refer to them,

although they have no bearing upon the subject under consideration. Symington (9) has shown that when the mouth of an infant is closed, so that the tongue is pressed against the palate and the cavity of the mouth is merely potential, the gums of the superior and inferior dental arches, instead of being in contact, are separated by an interval of 6 mm. This condition is well seen in Fig. 1, the interval between the gums being occupied partly by the edge of the tongue and partly by the folding inwards of the mucous membrane of the cheek, which becomes redundant when the mouth is closed. Notwithstanding the emaciated condition of the child, the fat of the sucking pad is still present.

Fig. 2, *L.G.*, *Sm.G.*, shows the intimate relation to the submaxillary salivary gland, of one of the lymph glands, which is here enlarged. This is a point worthy of note in regard to the pathology of angina Ludoviei, an affection which, in the writer's experience, is by no means unknown in children, and which is probably nothing more or less than an acute infective adenitis, along with extensive brawny periadenitis, originating, not in the salivary gland, but in the lymphatic gland.

A small proportion of hydrocephalic subjects reach adult life. The membranous areas then become completely ossified, partly by expansion of the ossifying process from the edges of the surrounding bones, but mainly by the formation of independent centres of ossification, resulting in the production of Wormian bones, which may be very numerous. In well-marked cases of hydrocephalus, the skull retains, to a considerable extent, the configuration above described as characteristic of the disease. The bones, however, never attain their normal thickness, and contain little or no diploe.

In the Anatomical Museum of the University, one of the skulls labelled "chronic hydrocephalus" (specimen N.A. i. 12) is of interest, inasmuch as, although possessing an abnormally large cranium, it is, nevertheless, wanting in almost all the features above described as characteristic of the disease. That it is the skull of an adult is evident from the well-marked muscular eminences, and from the prominences of the frontal sinuses. The horizontal circum-

ference of the cranium measures 24¾ in., that of an average cranium measuring 20 in. Its greatest length is 8½ in.; the greatest parietal breadth is 7 in.; and the basi-bregmatic height is 5¾ in. Its index of breadth is 85, thus resembling a typical hydrocephalic skull in being brachi-cephalic. The index of height is normal, namely 71. There is no bulging of the forehead, or of the parietal eminences. The greatest parietal breadth is only ½ in. more than the greatest frontal breadth. The posterior pole is formed by the occipital bone, and there is no vaulting of the base. The frontal suture is still present, while the greater part of the sagittal is obliterated. There are no Wormian bones. The supra-orbital arch and the orbital diameters are normal. There is no bulging of the middle fossæ, and the zygomatic arch is horizontal. Moreover, the face is not disproportionately small. There is, however, one point which should be mentioned in favour of hydrocephalus, namely, that the eminences and depressions upon the inner surfaces of the cranium are almost obliterated, and the calvarium is distinctly thinner than normal. The right half of the cerebellar fossa is considerably smaller than the left half, so that there is a decided want of symmetry in the occipital region. Sir George Humphry ([15]), in the paper already referred to, gives notes of five adult hydrocephalic skulls; and this one evidently belongs to the same category. Remarking upon his specimens, Humphry writes as follows:—"In these five adult crania the disproportion between the brain-case and the facial part is not so marked as in the infantile specimens, which is attributable in part to the predominant growth of the facial part in early extra-uterine life, and partly to the hydrocephalic disease being less in amount, and allowing the adult period to be reached, and the adult relation between the facial and the cranial parts to be, to a certain extent, attained; and it is to be remarked that the excessive growth of the cranial part of the skull is associated with, directly or indirectly productive of, some excessive growth of the facial parts. This also probably accounts for the fact that in most of the adult specimens the orbits have their natural shape, and do not present the obliquity in their roofs caused by the

pressure of the intra-ventricular fluid, which is so marked in the infantile specimens."

I shall now pass to the description of the brain and its membranes in the two cases.

In the post-mortem record of Dr. Carmichael's case, it is stated that the dura and its blood sinuses were normal, and that there were no adhesions between it and the arachnoid. There was a considerable increase of arachnoid fluid at the base, and the arachno-pia was œdematous.

In my own specimen, the dura, apart from being thin, was normal. The lower border of the falx was highly arched, and had dragged upwards the tentorium, so that on coronal section its two halves each formed a very obtuse angle with the falx (Fig. 5). The space thus left between the elevated tentorium and the upper surface of the cerebellum was occupied by a hernia-like diverticulum from the lateral ventricles (Fig. 4, *), about which more will be said later on. The cranial blood sinuses, as a result of the stretching of the dura and of the pressure exerted upon them from without, presented a triangular and, in some cases, a chink-like outline, the latter being the condition of the straight sinus (Fig. 5, *S.S.*), which was otherwise normal. There were no adhesions between the dura and arachnoid. The arachno-pia was examined for signs of meningitis, but none could be detected. The sub-arachnoid space in the inter-peduncular region contained a sheet of ice of some thickness, separated from that in the third ventricle by its thin, membrane-like floor. In order that the cisterna cerebello-medullaris and the parts about the roof of the fourth ventricle might be examined, the block from which Fig. 4 was taken was carefully dissected by removing the neural arches of the upper cervical vertebræ, the spinal dura, and a portion of the middle lobe of the cerebellum. It was found that the sub-arachnoid space was here practically obliterated by the jamming of the cerebellum down upon the posterior surface of the medulla, and that a somewhat condensed and adherent membrane intervened between the two. The foramen of Magendie was evidently closed. Since Hilton (7) drew attention to the closure of this foramen in basal meningitis, it has been frequently

referred to by subsequent writers, and put forward as an argument in support of the hypothesis that the majority of chronic as well as of acute cases of hydrocephalus are the result of a chronic basal lepto-meningitis, with or without a co-existent ependymitis. That such may be the pathogenesis

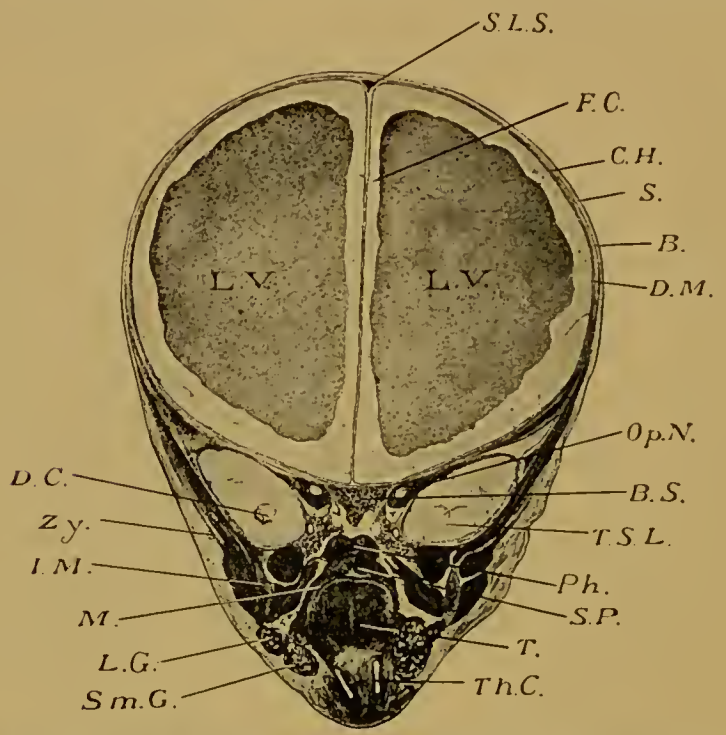


FIG. 2.—Coronal section, viewed from behind, passing through frontal and tips of temporo-sphenoidal lobes, sphenoid, soft palate, and root of tongue.

Op.N., optic nerve; *B.S.*, basi-sphenoid; *T.S.L.*, tip of temporo-sphenoidal lobe; *D.C.*, tip of descending cornu of lateral ventricle; *Zy.*, zygoma; *Ph.*, pharynx; *S.P.*, soft palate; *I.M.*, inferior maxilla; *L.G.*, lymphatic gland; *Sm.G.*, submaxillary gland; *Th.C.*, thyroid cartilage. Remaining lettering as in Fig. 1.

of some of the acquired forms of hydrocephalus, there can be no doubt, but that it is also the cause of the ordinary chronic form,—that is to say, of cases similar to the ones now under consideration,—I do not think there is sufficient evidence to show. On the contrary, it appears to the writer that to regard this obliteration of the sub-arachnoid space as responsible for the hydrocephalus, is to confuse cause and effect. In

the absence of any further evidence of meningitis, it seems much more reasonable to look upon the obliteration of the subarachnoid space between the cerebellum and medulla and the closure of the foramen of Magendie as secondary to the pressure exerted by the distended lateral ventricles. Were the hydrocephalus due to the closure of the foramen of Magendie, the fourth ventricle ought to be dilated, as well as the lateral and third ventricles. Such dilatation, however, is exceedingly rare.

The most striking condition presented by the brain in the two cases was, of course, their cystic condition, due to the accumulation of fluid within the lateral and third ventricles. Over the vertex the cerebral substance was reduced to a thickness of from 2 to 5 mm.,and the convolutions and sulci were completely effaced. What remained consisted almost entirely of grey matter. Owing to the much greater resistance offered by the base of the skull, the brain substance occupying this region was comparatively little altered, the convolutions and sulci being quite distinct. The grey matter appeared to be of almost normal thickness, but the white matter formed a comparatively thin layer (Figs. 3 and 4).

The cystic condition was confined to the lateral and third ventricles. In Figs. 3 and 4 the former are seen to have been converted into one huge sac, deeply indented by the fornix in the middle line above, and communicating freely with the third ventricle below. The intraventricular basal ganglia are usually described as broadened out and flattened. Such was their condition in the frozen brain, but no doubt the freezing had a large share in producing it. In Dr. Bruce's specimen (Plate XX.), the corpora striata and optic thalami, although broadened, appeared much more prominent than normal, in consequence of the way in which they had been thrown into relief, as it were, by the relatively much greater thinning of the parts of the brain adjacent to them. The anterior and posterior cornua were enormously dilated, the former occupying practically the whole of the anterior fossæ, and the latter stretching over the tentorium cerebelli to the posterior pole of the skull. The cornua of opposite sides were separated from each other by the falx, and the cerebral

mantle covering its lateral aspects. The descending cornua, owing to the greater thickness of the mantle of the tempero-sphenoidal lobes, were much less capacious. In my own specimen (Fig. 3) they measured $\frac{3}{4}$ in. in diameter; in Dr.

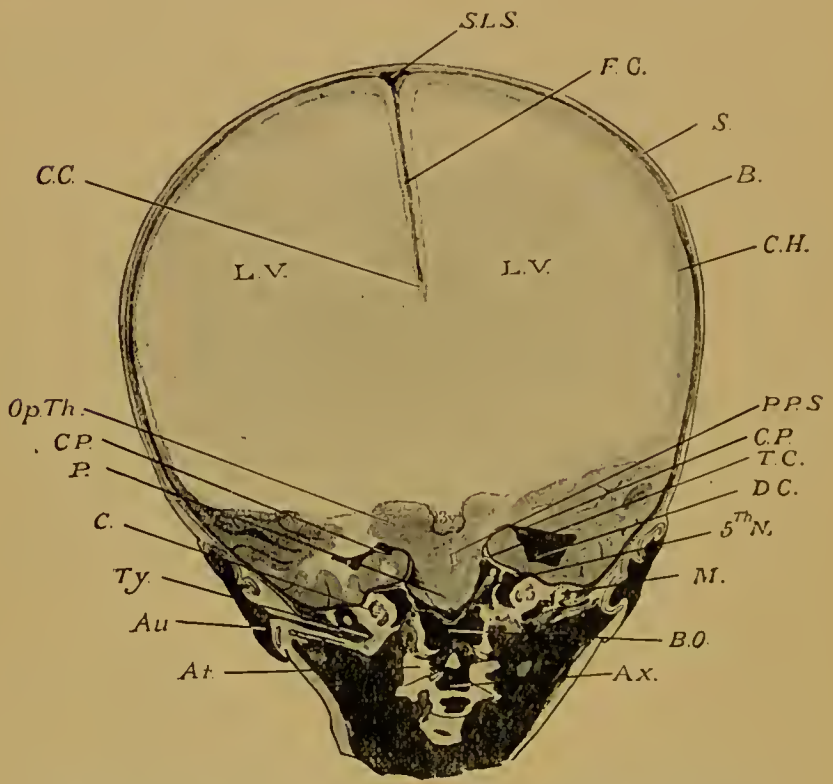


FIG. 3.—Coronal section, seen from before, passing through third and lateral ventricles, pores, basi-occiput, upper cervical vertebræ, and auditory apparatus.

C.C., corpus callosum; 3 *v.*, third ventricle; *Op.Th.*, optic thalamus; *P.P.S.*, posterior perforated spot; *P.*, pons; *D.C.*, descending cornu of lateral ventricle; *C.P.*, choroid plexus; *T.C.*, tentorium cerebelli; *5th N.*, fifth nerve; *C.*, cochlea; *Ty.*, tympanum; *M.*, malleus; *Au.*, auricle; *B.O.*, basi-occiput; *Ax.*, axis. Remaining lettering as in Fig. 2.

Bruce's, they appeared to have been more dilated, forming two wide, funnel-shaped excavations behind and beneath the posterior extremities of the caudate nuclei and optic thalami.

In both specimens the ependyma was very slightly thickened, but otherwise normal.

It may lead to a clearer conception of the morbid changes

which have been brought about by the disease, if it be pointed out, at the outset, that the cerebral hemispheres become converted into one huge, hourglass-shaped cyst, the shape of which is dependent upon the dura and its processes, to the surface of which it becomes moulded.

As the lateral ventricles become dilated, the corpus callosum is gradually raised up from the fornix. The subarachnoid space at the bottom of the great longitudinal fissure soon becomes obliterated by the upper surface of the corpus callosum coming in contact with the lower edge of the falx cerebri. Ultimately the corpus callosum can no longer be detected as an independent structure, although theoretically, of course, it is represented by the very thin strand of white matter running along the lower edge of the falx (Fig. 3, *C.C.*). The septum lucidum becomes stretched, and usually disappears altogether, as has happened in my own case. In Dr. Bruce's specimen (Plate XX., *S.L.*) it is represented merely by three slender cords — one on the right side and two on the left—extending from the corresponding half of the anterior part of the fornix forwards and upwards, to be attached to, and lost upon, the thin layer of brain substance reflected over the lower edge of the anterior part of the falx, and representing the remains of the corpus callosum. In length these cords measured 4 cm., and were of the thickness of medium-sized surgical catgut. In all probability they are the remains of the obliterated veins of the septum lucidum, and are the only structures left to represent that organ. The highly arched condition of the falx, and the elevation and disappearance, practically, both of the corpus callosum and of the septum lucidum, throw the lateral ventricles into free communication with each other through a large, oval opening occupying the mesial plane. This opening is bounded above by the lower edge of the falx (covered by the remains of the corpus callosum); below, by the anterior pillars of the fornix, the anterior part of the third ventricle, and the velum and interpositum; in front, by the anterior recurved extremity of the lower edge of the falx; posteriorly, by its junction with the tentorium cerebelli. In Dr. Bruce's specimen the

aperture measured 4 cm. from before, backwards; in my own case it measured 6 cm. from above, downwards (Figs. 3 and 4).

The statements regarding the fate of the fornix vary

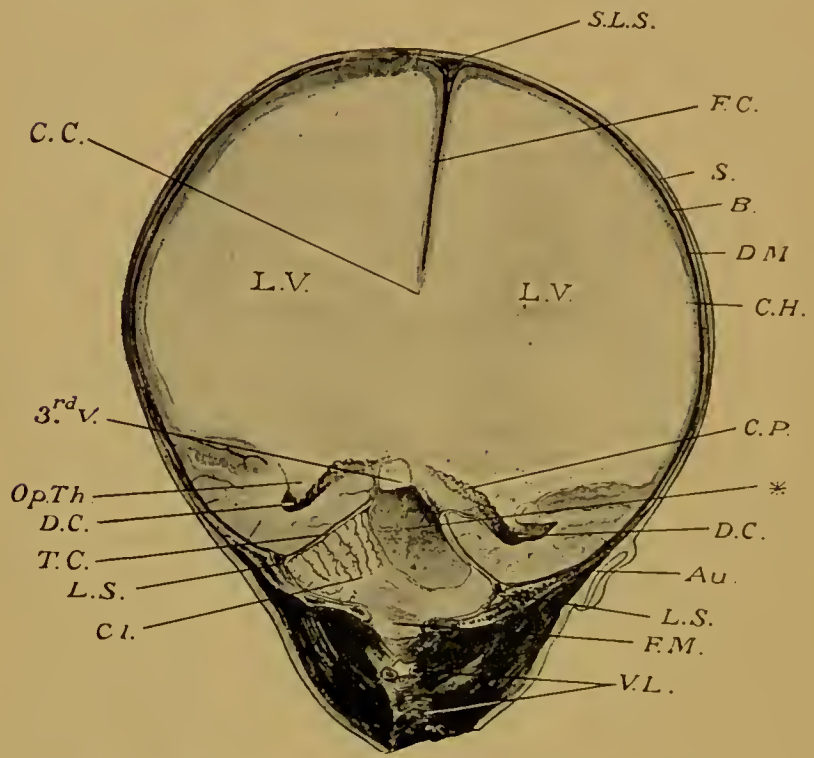


FIG. 4.—Coronal section at the level of the great transverse fissure, viewed from behind, and passing through posterior part of third ventricle, commencement of descending cornua of the lateral ventricles, cerebellum, posterior part of foramen magnum, and laminæ of upper cervical vertebræ.

C.P., choroid plexus; *3rd V.*, posterior part of third ventricle; *Op.Th.*, posterior extremity of optic thalamus; *D.C.*, descending cornu of lateral ventricle; *L.S.*, lateral sinus; *Cl.*, cerebellum; *F.M.*, foramen magnum; *V.L.*, vertebral laminæ; *, sub-tentorial diverticulum of lateral ventricles. Remaining lettering as in Fig. 3.

considerably. In a specimen described by John Thomson ([12]) it was said to be absent. Dickinson ([2]) refers to it as being diffluent. West ([13]), on the other hand, states that "in seven post-mortem examinations of children affected with chronic internal hydrocephalus, he found the fornix present in all; in three, it and the septum lucidum

were thickened and tough; in two, they were torn and softened (the result of a subsequent acute inflammation); in one the septum lucidum was absent; and in one, both it and a large portion of the fornix were wanting." In the text-books on nervous diseases no mention whatever is made of the fornix. The question as to the presence or absence of this structure is of some importance, as helping to determine how far the hydrocephalus is to be regarded as an arrest of development, and if so, at what stage the arrest begins.

In Dr. Bruce's specimen there was no doubt about the fornix having been developed. In Plate XX. (*F.*), the anterior pillars are seen as two rounded cords, 2 mm. in thickness, arching upwards above the anterior part of the third ventricle; traced forwards, they are seen to bend downwards and converge at the anterior part of the third ventricle, where, after forming the corpora albicantia (*C.A.*), they diverge from one another, and finally become lost upon the inner surface of the optic thalami. Tapering and converging as they arch backwards, they ultimately join upon the upper surface of the velum interpositum, a little behind the meeting-point of the anterior extremities of the choroid plexuses. After the anterior pillars have joined, the fornix can no longer be traced as an independent structure, but the body appears to be represented by a thin layer of white matter covering the remains of the velum interpositum, which stretches over the posterior part of the third ventricle from one optic thalamus to the other. Faint indications of the posterior pillars are seen in the shape of two slight elevations winding over the posterior extremities (pulvinar) of the optic thalami, and thence onwards to be lost upon the wall of the descending cornua of the lateral ventricles. In the frozen slabs it was at first difficult to speak with certainty as to the fornix. In the notes taken at the time of dissection, I find it stated that no trace either of the body or of the posterior pillars could be discovered; but on dissecting the posterior surface of the slab, which displayed a section through the anterior part of the third ventricle, two white cords were seen curving downwards in front of the third

ventricle towards its floor, where they diverged from each other and then became lost upon the optic thalami. There can be little doubt, I think, that from their position and connections these structures represent the anterior pillars of the fornix.

In this slab, and the one immediately behind it (Fig. 3),

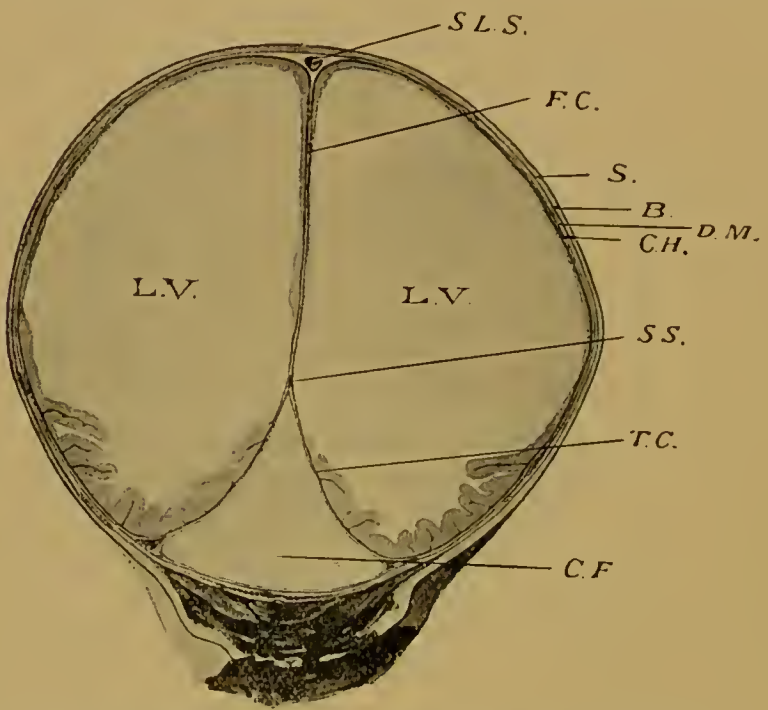


FIG. 5.—Coronal section, viewed from behind, passing through occipital lobes, tentorium cerebelli, cerebellar fossa, and occipital bone behind foramen magnum.

L.V., posterior cornua of lateral ventricles; *S.S.*, straight sinus; *T.C.*, tentorium cerebelli; *C.F.*, cerebellar fossa. Remaining lettering as in previous figures.

the third ventricle presented itself as a trough-like depression bounded by the optic thalami on either side, and opening above directly into the fused lateral ventricles. The anterior or infundibular portion was deepened to form a sac-like diverticulum, beneath which was the optic commissure, somewhat flattened.

In neither of the two specimens did the choroid plexuses of the lateral ventricles present any morbid condition of importance. In Dr. Bruce's specimen each contained a small

cyst about half the size of a pea. Such cysts are quite commonly met with in conditions apart altogether from hydrocephalus, and are, therefore, of no importance. In Fig. 4, which represents a section opposite the great transverse fissure, the choroid plexuses are seen stretching almost transversely across the optic thalami, round the posterior extremities of which they wind, to disappear into the descending cornua of the ventricles. Between the plexuses is the velum interpositum, which, owing to the widening out of the foramen of Monro, stretches forwards only for a very short distance, and therefore roofs over only the posterior part of the third ventricle. Upon its under surface the two shortened choroid plexuses of the third ventricle could be made out. In both specimens the upper surface of the velum is covered with ependyma, continuous with that lining the lateral ventricles. In the Müller specimen, some fibres of the fornix appeared to intervene between the ependyma and the velum; but it was impossible to say whether this was the case also in the frozen brain.

The aperture seen just below the velum (Fig. 4, *3rd V.*) is a section of a diverticulum which extended backwards from the third ventricle. It contained a small block of ice which, when traced through to the anterior surface of the slab, was found to be directly continuous with the ice occupying the posterior part of the third ventricle. From its position and relations, this diverticulum no doubt represents the hollow stalk of the pineal gland (and probably also the gland itself, since this structure could not be discovered), which had been dilated into a small sac. It projected into, and was surrounded by, a second and much larger sac (Fig. 4, *), which has already been referred to as intervening between the under surface of the tentorium and the upper surface of the cerebellum. On removing the block of ice from this sac, it was found to be lined by ependyma, directly continuous, through the opening in the tentorium, with that which we have just seen covering the upper surface of the velum interpositum, and through it, again, with the ependyma of the lateral ventricles. On tracing the ependyma of the sac backwards, it was reflected upwards on to the under surface of the

tentorium, and thence over its edge and round the margin of the limbic lobe (gyrus fornicatus) of each hemisphere into the lateral ventricles again. Externally, the ependyma was covered with pia mater, the two being intimately blended, and forming together the wall of the sac.

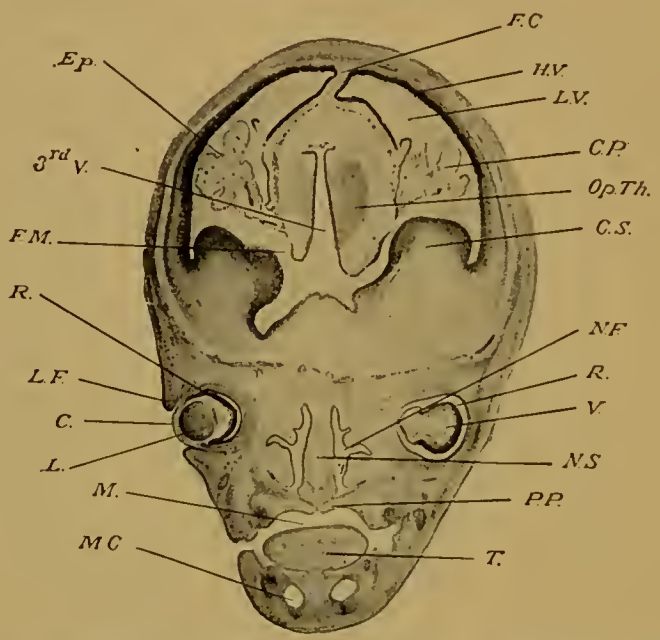


FIG. 6.—From a photograph of a mieroseopie coronal section of the head of a seventh-week human embryo, illustrating the development of the fore-brain.

F. C., falx cerebri; *H. V.*, hemisphere vesiele; *L. V.*, lateral ventricle; *C.P.* choroid plexus; *Ep.*, its epithelial covering, continuous with and derived from the inner wall of the hemisphere vesiele; *3rd V.*, third ventricle; *Op. Th.*, anterior end of optic thalamus; *C.S.*, corpus striatum; *F.M.*, foramen of Monro; *R.*, retina; *V.*, vitreous; *L.*, lens; *C.*, cornea; *L.F.*, lid fold; *N.F.*, nasal fossa and rudimentary turbinals; *N.S.*, nasal septum; *P.P.*, palatal process, about to fuse with its fellow and with the lower edge of the nasal septum; *M.*, mouth; *T.*, tongue; *M.C.*, Meekel's cartilage.

In order to understand the real nature and mode of formation of this sac, we must refer for a moment to the normal brain, and examine the relation of parts seen in a vertical coronal section at the level of the posterior part of the corpus callosum. Below, and upon either side of this structure, are the two lateral ventricles cut across just in front of their bifurcation into the posterior and descend-

ing cornua. The floor is here formed by the posterior part of the upper surface of the optic thalamus, resting upon which is the choroid plexus and the posterior part of the body of the fornix, just where it gives off the descending pillar. The two ventricles are here partitioned off by the adhesion of the apposed surfaces of the corpus callosum and fornix. This union is by no means a firm one even in the normal brain; indeed, a small compressed cavity (Verga's ventricle) sometimes exists between the two. Beneath the posterior part of the corpus callosum and the commencement of the posterior pillars of the fornix is the middle part of the great transverse fissure occupied by the fold of pia mater, which is projected forwards over the corpora quadrigemina, and thence onwards to form the roof of the third ventricle.

Now, as the head enlarges, and the lateral ventricles become distended, the corpus callosum and septum lucidum become stretched, and ultimately more or less absorbed, so that the bodies of the lateral ventricles are thrown into free communication with one another above the anterior pillars of the fornix. The next thing that happens is that the corpus callosum becomes gradually stripped from before backwards from off the fornix, so that Verga's ventricle becomes a part of the fused bodies of the lateral ventricles. Meanwhile the body of the fornix, becoming thinner and thinner, can no longer be recognised as an independent structure; and the fused lateral ventricles, which extend farther and farther backwards as they dilate, come at length to overlap the upper surface of the velum interpositum as far back as where the lower edge of the falx joins the anterior edge of the tentorium. In our own specimen this diverticulum of the lateral ventricles has, in consequence of the dragging upwards of the tentorium by the falx, extended still farther backwards, and formed a sac-like extension between it and the upper surfaces of the corpora quadrigemina and cerebellum. The only references I have been able to find to a condition in any way approaching this are by Dickinson (2) and by Gowers (4). The former refers to a case in which "there was a sort of extra ventricle formed by the separation of the tentorium from the upper surface of the cerebellum, this cavity being in free com-

munication with each lateral ventricle by a large round opening at the outer part of the transverse fissure on either side." There can, I think, be little doubt that we have here again to do with a diverticulum of the lateral ventricle, originating in the way above described. Gowers, in referring to the raising of the tentorium by the stretching of the falx cerebri, mentions that this increases the size of the subtentorial space which "is not completely filled by the cerebellum, the interval being occupied by liquid and sometimes by loose connective tissue." In our own specimen, the effect of this hernial condition was to drive the cerebellum downwards and forwards so as to flatten and compress it against the floor of the cerebellar fossa (Fig. 4, *Cl.*). The greater part of the medulla, the cerebellar tonsils, and part of the inferior vermiform process, were all displaced through the foramen magnum into the spinal canal. There was no dilatation of the fourth ventricle. The spinal cord appeared to be normal, and there was no dilatation of the central canal. In Dr. Bruce's specimen there was no subtentorial diverticulum of the lateral ventricles, but their fused bodies extended over the velum interpositum as far as the anterior edge of the tentorium.

The form and relations of the parts about the third ventricle are well seen in Plate XX. The third ventricle, related as it is to the unyielding base of the skull, and supported by the basal ganglia, undergoes, apart from dilatation, comparatively speaking, but little modification. Anteroposteriorly, from the lamina terminalis to the posterior commissure, it measured 3 cm.; at its widest part, opposite the anterior extremities of the optic thalami and the foramen of Monro, it measured 11 mm. Its deepest part, measuring 17 mm., is situated anteriorly, and corresponds to the infundibular region. Here it forms a well-like extension, which, when viewed from the exterior, appears as a somewhat thin-walled, bladder-like protrusion, upon which the optic commissure rests. This anterior or infundibular region of the third ventricle opens above directly into the confluent bodies of the lateral ventricles through an oval opening, measuring 18 × 8 mm., situated between the anterior pillars of the

fornix. The foramen of Monro, in this specimen, is converted into a triangular aperture (Plate XX., *F.M.*) measuring 11 × 4 mm.; it is bounded above and in front by the anterior pillars of the fornix, below and behind by the anterior part of the optic thalamis. Through the narrow posterior extremity of the opening, the anterior end of the choroid plexuses of the lateral ventricles wind round on to the under surface of the roof of the third ventricle. By many authors, the foramen of Monro is described as being very much larger than above stated. In the case described by Dickinson ([2]), in which the circumference of the head measured 30 in., the foramen of Monro is said to have been stretched to a diameter of $3\frac{1}{2}$ in. "It was not quite circular in shape, and was crossed by filaments of pia mater. From the edges of this opening two thin laminæ of cerebral tissue passed vertically, and formed the inner wall of each lateral ventricle." It appears more than probable that the aperture here referred to is not, strictly speaking, the foramen of Monro, but the large oval aperture which has been already described as existing between the lower edge of the falx and the third ventricle. The "filaments of pia mater" no doubt represent the remains of the septum lucidum, and correspond to the delicate cords described in Dr. Bruce's specimen as stretching across the opening from the anterior pillars of the fornix to the lower edge of the falx. In John Thomson's ([12]) specimen the foramen of Monro is described as being enormously dilated, and measuring $1\frac{1}{4}$ in. in diameter. In his specimen, however, the fornix could not be made out, so that here again it is probable the foramen of Monro and the space produced by the elevation of the corpus callosum have been thrown into one. A similar condition appears to have been brought about in my own specimen.

To return to Dr. Bruce's specimen (Plate XX.). On looking into the third ventricle from the front, a rounded aperture, of the diameter of a crow quill, led into a cavity which extended backwards for a distance of $1\frac{1}{2}$ cm. At first sight this appeared to be either a diverticulum of the third ventricle occupying the pineal region, or the dilated aque-

duct of Sylvius. When further investigated, by cutting into it from above, it was found that neither surmise was correct; we had to do simply with the posterior part of the third ventricle, namely, the part which slopes upwards and backwards towards the aqueduct, under cover of the remains of the body of the fornix, which, as we have seen, was spread out upon the upper surface of the velum interpositum. The rounded opening leading into this part of the ventricle was bounded, above, by the fork-like divergence of the anterior pillars of the fornix; below, by what turned out to be the middle commissure (Plate XX., *M.C.*).

In all the descriptions I have been able to refer to, the middle commissure is stated to be absent. In the specimen before us it was present in the form of a thick cord-like structure measuring 4 mm. in length and 3 mm. in thickness, and uniting the inner surfaces of the optic thalami about midway between their anterior and posterior extremities. The posterior commissure (Plate XX., *P.C.*), although a much more delicate structure, could be satisfactorily identified at some little distance above and behind the entrance to the aqueduct. The pineal gland could not be discovered. As in the frozen specimen, owing to the widening of the foramen of Monro, the choroid plexuses of the lateral ventricles stretched almost horizontally across the optic thalami from one descending cornu to the other.

The mid-brain did not present any noteworthy alterations in either of the two cases. In Dr. Bruce's specimen it appeared to be perfectly normal; there was not even any flattening of the quadrigeminal bodies. The aqueduct of Sylvius was certainly not dilated; indeed, it was a question as to whether its anterior end was even patent, but this point can only be settled by a microscopic examination, which I have had no opportunity of making. In the frozen specimen, the quadrigeminal bodies were flattened almost beyond recognition by the block of ice which occupied the posterior diverticulum of the lateral ventricles. The aqueduct appeared to have been obliterated by pressure. In the Müller specimen, without careful dissection, the posterior part of the third ventricle (Plate XX., *3rd Vb.*) might so easily be mistaken

for a dilated aqueduct, that it is more than probable this error has actually been committed in the reports of post-mortem examinations of hydrocephalic brains. The funnel-shaped dilatation, which is sometimes referred to as occurring at the anterior end of the aqueduct, may, in some cases, have been nothing more or less than the posterior part of the third ventricle.

Pathogenesis.

"This subject," says Hamilton ([5]), "is so complicated that it would be injudicious to say much about it; there are so many possibilities, and so few facts to support them, that it would require much definite experimental evidence to arrive at anything like a satisfactory conclusion." While fully appreciating both the difficulty and the obscurity of the subject, I think that, after a careful inquiry into the morbid anatomy of the disease, a few remarks on the pathogenesis of the condition may be permitted, even at the risk of not being able to make any important addition towards the solution of the problem. I shall confine my remarks to those cases in which no obvious lesion exists to account for the hydrocephalus.

Several more or less plausible explanations of the condition have been put forward, but none of them can be said to have advanced much beyond the stage of hypothesis. That in many cases the affection is already so far advanced at birth as to give rise to difficulty in the passage of the head along the maternal passages, is of course well known. It should be remembered also, that the ventricles may be markedly dilated without giving rise to any enlargement of the head, and that this may occur in infants as well as in adults. Such cases have been described, more especially by Chiari ([1]). It is only fair to suppose that in those cases in which the head begins to enlarge within a few weeks or months after birth, and in which no obvious cause or lesion is discoverable post-mortem, that the condition is here also probably congenital.

Admitting, then, the congenital origin of the two cases I have described, we have next to consider their causation. We

have already seen that nothing was discovered pointing to an inflammatory origin; the condensation of the arachno-pia between the cerebellum and the medulla is to be regarded as the result, rather than the cause, of the hydrocephalus. According to Dickinson ([2]), Francis Miles ([8]), and others, such non-inflammatory hydrocephalic conditions result from the extra intra-cranial pressure caused by whooping cough, chronic bronchitis, crying, etc., acting upon a cranial box, the resistance of which has been diminished by mal-nutrition, more especially that associated with rickets. Such a close etiological relationship between rickets and hydrocephalus cannot be established, and most writers on the subject refuse to accept this explanation, and, I think, with much reason upon their side.

The influence of syphilis, while denied by some, is regarded as an important cause of hydrocephalus by Heller ([6]), Titomanlio ([11]), and others. That a definite history of syphilis can be got in a number of cases is certain, but it is equally certain that in many cases no such taint exists. That the disease sometimes affects more than one member of a family points just as much to a congenital arrest of development as it does to syphilis. It is only after sufficiently reliable and numerous statistics have been obtained, that we can rightly estimate the importance of specific disease in the causation of hydrocephalus. Even admitting its influence, it is difficult to say whether it acts by interfering with the development and resistance of the cranial wall, or by giving rise to chronic basal meningitis. The beneficial effects which have been observed to follow the administration of mercury in a few cases, may be explained on the assumption of their specific origin.

Alcoholism in the parents can hardly be regarded as of primary importance in the etiology.

To content ourselves by saying that the condition is an "essential dropsy," is nothing more or less than to confess our ignorance: it brings us no nearer the truth, and leaves us with the cause of the dropsy still to be accounted for. When the disease has advanced to a certain degree, a dropsical element is no doubt superadded, due to the intra-cranial

pressure, interfering with the venous return to a greater extent than with the inflow through the arteries.

We are thus brought to consider how far the hydrocephalus is to be regarded as dependent upon an arrest in the development of the brain. It appears to the writer that the balance of evidence is in favour of this mode of origin. In the first place, we have the fact that in many cases the hydrocephalus is already existent at birth, and it is difficult to account for this upon a purely inflammatory hypothesis. Again, in many cases spina bifida co-exists along with the hydrocephalus. This occurred in 9 out of 21 cases described by Chiari (1); in one there was extroversion of the bladder and a congenital abnormality of the liver. According to Recklinghausen, the primary error in spina bifida consists in the arrest of development of the mesoblastic elements, which go to embrace the cord and to close in the posterior median line of the body. Thoma (10), on the other hand, regards this as secondary, and dependent on late closure or persistent patency of the medullary groove. In the rare congenital condition known as salpingomyelus, where the whole spinal canal is dilated, we have a condition analogous to what occurs in congenital hydrocephalus, along with which, indeed, it sometimes, though rarely, co-exists. It has been shown that hydrocephalus may occur very early in fœtal life, and, according to Förster (3) and others, a certain proportion of cases of cranioschisis owe their origin to rupture of an embryonic hydrocephalic brain.

Chiari (1), in an elaborate monograph, has pointed out that in congenital hydrocephalus important alterations are not infrequently found in the cerebellum and medulla. In 22 per cent. the tonsils and inferior vermiform processes of the cerebellum accompany the medulla into the spinal canal in the form of a plug-like extension. In one instance this process extended down to the origin of the fourth cranial nerve. Chiari regards this downward extension of the cerebellum not as a passive process, but as the result of the growth of the tonsils into the only space available. The remainder of the cerebellum is flattened, but otherwise normal. The above changes show that the hydrocephalus occurs before the cerebellum

has developed, thus proving its congenital origin. In 11 per cent. of the cases the fourth ventricle extended into the spinal canal in the form of a pouch, containing within it an extension of the vermiform process. Chiari explains this condition by supposing that the hydrocephalus had begun at a much earlier date, that is to say, at a time when the dorsal wall of the posterior cerebral vesicle is less completely developed, the result being that the subsequent hydrocephalus tells specially upon the fourth ventricle. In one of the cases recorded by Chiari, the child was operated upon for a supposed cervical spina bifida. This, on post-mortem examination, turned out to be the dilated fourth ventricle, which, along with almost the whole of the imperfectly developed cerebellum, formed a cystic swelling projecting from a cleft in the cervical region, involving the three upper cervical vertebræ. The lateral and third ventricles, and the aqueduct, were all widely dilated; and it is interesting to note, also, that the tentorium cerebelli was represented merely by two narrow processes attached to the petrous bone. This case, therefore, well illustrates the close relationship which exists between hydrocephalus and spina bifida.

By reference to other developmental conditions of the brain, further evidence might be adduced in favour of congenital hydrocephalus being essentially an arrest of development of the brain: for instance, when the corpus callosum is absent, the lateral and third ventricles are markedly dilated.

In order that the nature of the developmental arrest which gives rise to hydrocephalus may be better understood, I may refer shortly to Fig. 6, which represents a microphotograph of a preparation selected from a complete series of vertical coronal sections which I have made through the head of a seventh-week human embryo which was kindly sent me by Dr. Arthur Stiles of Spalding. It shows remarkably well the condition of the brain at this period of its development. The cerebral hemispheres are represented by two hollow vesicles separated by a process of vascular mesoblastic tissue in which the falx cerebri is developed. The wall of each vesicle, except at its base, is thin, so that

the cavity, representing the lateral ventricle, is relatively very large. The inner wall of the hemisphere is reduced, at its lower part, to a single layer of cubical cells. It is in this situation (represented at a still earlier stage by a fold in the wall, called the choroidal fold) that the mesoblast which covers the hemisphere grows out into the ventricle in the form of a pedunculated and somewhat branching mass of delicate vascular tissue—the choroidal plexus. This structure, strictly speaking, is outside the cavity of the ventricle, being covered by the single layer of epithelium, which, morphologically speaking, represents the invaginated wall of the hemisphere.

Between, and overlapped by the primitive hemispheres, is the basal portion or stalk of the original anterior primary cerebral vesicle, the cavity of which has been reduced to a deep slit-like space representing the anterior part of the third ventricle. The roof, which is seen to be very thin, is, in the adult, represented merely by the layer of endothelium covering the under surface of the velum interpositum. The choroid plexuses of the third ventricle have not yet developed. The slit-like character of the cavity of the third ventricle is due to the thickening which takes place in its lateral walls, forming the optic thalami, the anterior extremities of which are seen in section. The apertures (really canals) which are seen connecting the third ventricle and the lateral ventricles represent the foramen of Monro, which at this period of development is still of a considerable size. In sections a little farther back in the series, that is to say behind the foramen of Monro, the corpora striata and optic thalami fuse with one another, so that in this situation the lateral ventricles appear to have no communication with the third ventricle.

If we now compare the brain of this seventh-week embryo with the hydrocephalic brains just described, we shall find that the resemblance is largely confined to the condition of the cerebral hemispheres; in both, the ventricles are cystic, and the cerebral mantle exceedingly thin. On examining the cerebral mantle of the embryo brain more closely, we find that it contains very little white matter

Here, just as in the spinal cord, the white matter develops at a later period. This may possibly serve to explain how it is that in hydroeephalus the cerebral mantle is represented almost entirely by grey matter, and why the eorpus callosum is so imperfectly developed. Of course, it may be argued that these structures have been developed, but have subsequently atrophied from pressure. It is diffieult to say which of the two factors is the more important. On comparing the remaining parts of the hydrocephalie brains with that of the embryo, we find that in the former the parts, with the exception of the corpus callosum, and possibly also of the fornix, are all present in a comparatively well-developed condition. It would seem, therefore, that the arrest of development, assuming it to exist, is almost restricted to the hemisphere vesicles. As to the cause of the arrest, nothing is known. If it be primary, and if it does not involve the cranial box, then the ventricles become filled with cerebro-spinal fluid to occupy the vacuum (hydrops ex vacuo); more probably, however, the arrest is secondary to an undue seeretion poured out by the vital activity of the cells covering the coroid plexus, cells which appear to undergo a specialisation both of structure, and probably also of function, at a comparatively early stage of development. Should this occur, it is easy to see how the inereased pressure within the lateral ventricles would lead to the arrest of development and to the permanently cystic condition of the hemisphere vessels, followed, in the majority of instanees, by an expansion of the mesoblastic structures which support them. It is interesting to note, in this relation, that hydrammios has frequently been observed to exist along with hydrocephalus of the fœtus. The fluid in hydrocephalus appears to have the same composition as cerebrospinal fluid, a fluid which, in eonsequenee of the absence of albumen, of the presence of a eopper-redueing substance, and, according to Halliburton, the presence also of albumoses, is regarded by physiologists as a secretion due to the vital properties of the eells lining the choroid plexuses, and possibly also of those lining the ventricle generally.

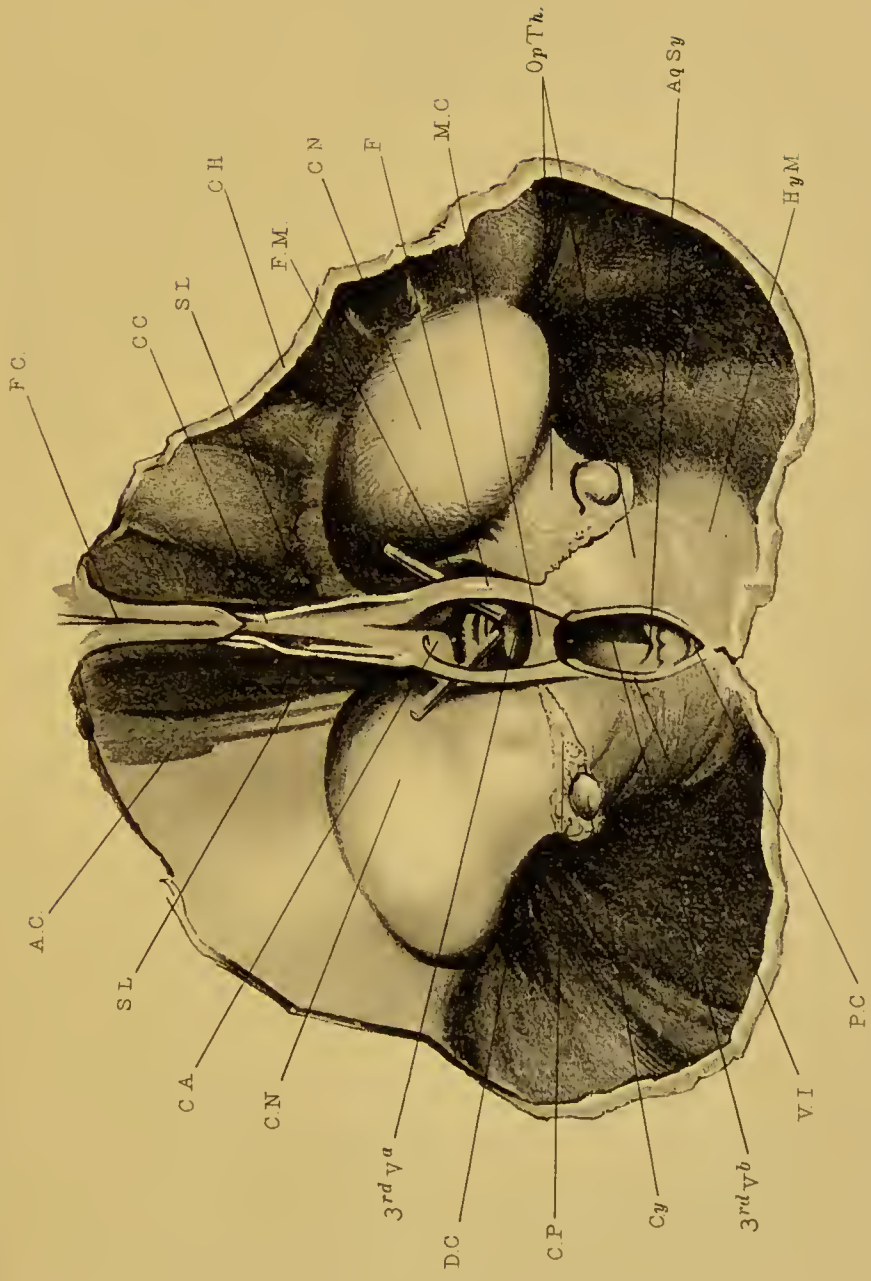
REFERENCES.

1. Chiari . . . . "Ueber Veränderungen des Kleinhirns, des Pons und der Medulla Oblongata in folge von congenitaler Hydrocephalie des Grosshirns," Wien, 1895.
2. Dickinson . . "Lectures on Chronic Hydrocephalus," *Lancet*, London, 1870, vol. ii.
3. Förster . . . "Die Missbildungen des Menschen," Jena, 1865.
4. Gowers . . . "Diseases of the Nervous System," 1893, vol. ii. p. 586.
5. Hamilton . . . "Text-Book of Pathology," 1889, vol. i. p. 334.
6. Heller . . . *Deutsche med. Wchnschr.*, June 30, 1892.
7. Hilton . . . "Rest and Pain," 1892, p. 38.
8. Miles . . . . "Cyclopædia of the Diseases of Children," edited by J. M. Keating, 1890, vol. iv. p. 473.
9. Symington . . "The Topographical Anatomy of the Child," Edinburgh, 1887.
10. Thoma . . . . "Text-Book of General Pathology and Pathological Anatomy," translated by Alexander Bruce, M.D., 1896, vol. i. p. 215.
11. Titomanlio . . Eleventh International Medical Congress, Rome, 1894.
12. Thomson, John . "A Case of Chronic Internal Hydrocephalus," *Arch. Pediat.*, N. Y., 1892, vol. ix. p. 779.
13. West . . . . "Lectures on the Diseases of Infancy and Childhood," 1874, p. 126.
14. Hern . . . . *Brit. Med. Journ.*, London, 1893, vol. ii. p. 1046.
15. Humphry . . . "The Microcephalic or Idiot Skull, and the Macrocephalic or Hydrocephalic Skull," *Journ. Anat. and Physiol.*, London, 1895, vol. xxix. p. 304.

DESCRIPTION OF PLATE XX.

Third ventricle and floors of lateral ventricles, viewed from above. (Dr. Bruce's specimen ; natural size.)

F.C., falx cerebri ; *C.C.*, corpus callosum ; *S.L.*, remains of septum lucidum ; *C.H.*, wall of cerebral hemisphere ; *F.M.*, foramen of Monro ; *C.N.*, caudate nucleus ; *F.*, fornix ; *M.C.*, middle commissure ; *Op.Th.*, optic thalamus ; *Aq. Sy.*, aqueduct of Sylvius ; *Hy.M.*, hypocampus major ; *P.C.*, posterior commissure ; *V.I.*, cut edge of velum interpositum, covered by fibres of fornix ; *3rd Vb.*, posterior part of third ventricle ; *Cy.*, choroidal cyst ; *C.P.*, choroid plexus ; *D.C.*, descending cornu of lateral ventricle ; *3rd Va.*, anterior part of third ventricle ; *C.A.*, corpus albicans ; *A.C.*, anterior cornu of lateral ventricle.


F C
C C
S L
C H
F M
C N
F
M.C
Op Th.
Aq Sy
Hy M
A.C
S L
C A
C N
3rd v a
D C
C P
Cy
3rd v b
V I
P C